In the Specification:

[0002] In electrophotographic ~~printing~~ imaging devices, toner particles are used to form a desired image on ~~the~~a print medium, which is usually some type of paper. Once the toner ~~is~~particles are applied to the paper, the paper is advanced along a paper path to a fuser. In many printers, copiers and other electrophotographic printing devices, the fuser includes a heated fusing roller engaged by a mating pressure roller. As the paper passes between the rollers, toner ~~is~~particles are fused to the paper through a process of heat and pressure.

[0004] The present invention provides a new and useful fuser sensing method and system ~~of that cures the above problems and others~~.

[0021] Illustrated in Figure 1 is a simplified cross sectional view of an exemplary electrophotographic imaging device, such as an electrophotographic printer **10**, in accordance with one embodiment of the present invention. The printer **10** includes, for example, a charge roller **15** that charges the surface of a photoconductor, such as an organic photoconductor drum **20**, to a predetermined voltage. A laser scanner **25** includes a laser diode (not shown) that emits a laser beam **30** onto the photoconductor drum **20** to selectively discharge its surface. The laser beam **30** is reflected off a multifaceted spinning mirror (not shown) that reflects or "scans" the laser beam **30** across the surface of the photoconductor drum **20** forming a latent electrostatic image corresponding to ~~the~~ data being printed. The photoconductor drum **20** rotates in a clockwise direction as shown by the arrow **35** such that each successive scan of the laser beam **30** is recorded on the photoconductor drum **20** after the previous scan.

[0023] With further reference to Figure 1, after the surface voltage of the photoconductor drum **20** has been selectively discharged, a developing device, such as a developing roller **40**, transfers toner **45** to the surface of the photoconductor drum **20**. Toner **45**, for example, is stored in a toner reservoir **50** of a toner print cartridge **55**. A magnet (not shown) located within the developing roller **40** magnetically attracts the toner **45** to the surface of the developing roller **40**. As the developing roller **40** rotates, the toner **45** is electrostatically transferred from the

developing roller 40 to the discharged surface areas on the photoconductor drum **20** thus covering the latent electrostatic image with toner particles.

[0024] A print media **75**, such as paper, envelopes, transparencies~~, etc.,~~ and the like is loaded from a media tray **80** by a pickup roller **85** and travels in a printing path in the electrophotographic printer **10**. The print media **75** moves through drive rollers **90** so that the arrival of the leading edge of the print media **75** at a transfer point below the photoconductor drum **20** is synchronized with the rotation of the latent electrostatic image on the photoconductor drum **20**. There, an image transfer device, such as a transfer roller **95**, charges the print media 75 so that it attracts the toner particles away from the surface of the photoconductor drum **20**. As the photoconductor drum **20** rotates, the toner 45 adhered to the discharged areas contacts the charged print media **75** and is transferred thereto.

[0025] The transfer of toner particles from the photoconductor drum **20** to the surface of the print media **75** is not always complete and some toner particles may remain on the photoconductor drum **20**. To clean the photoconductor drum **20**, a cleaning blade **100** may be included to remove non-transferred toner particles as the photoconductor drum 20 continues to rotate and the toner particles are deposited in a toner waste hopper **105**. The photoconductor drum 20 may then be completely discharged by discharge lamps (not shown) before a uniform charge is restored to the photoconductor drum **20** by the ~~charging~~charge roller **15** in preparation for the next image generation and toner transfer. In general, the image generation and transfer system of the ~~imaging device~~electrophotographic printer **10** includes the laser scanner **25**, the ~~photosensitive~~photoconductive drum **20**, a drum charging device such as the charge roller **15**, a toner transfer device such as the developing roller **40**, and an image transfer device such as the transfer roller **95**. It will be appreciated that other components can be characterized as part of the system including every component in the image device **10** since each plays a role in the image generation and transfer to the print media 75.

[0026] As the print media **75** moves in the printing path past the photoconductor drum **20** and the transfer roller **95**, it enters a post transfer area. There, a conveyer **110** delivers the print media **75** to a fixing device, such as a heated fuser roller **115** and a heated pressure roller **120**,

generally referred to herein as a fuser. The rollers **115, 120** are in pressure engagement with each other and form a nip at ~~the~~their contact point. As the print media passes between the rollers **115, 120** through the nip, the toner **45** is fused to the print media through a process of heat and pressure. One or both rollers **115, 120** are motor driven to advance the print media **75** between them. In one embodiment, the fuser is an on-demand fuser and the fuser roller **115** includes, for example, a flexible rotating sleeve that surrounds a carrier which holds a ceramic heating device **117**. The carrier provides structure to the fuser roller **115** so that pressure may be applied against the pressure roller **120**. The flexible sleeve is typically made of polyimide. Alternately, the fuser roller 115 can be a hard roller constructed with a hollow metal core and an outer layer often made of a hard "release" material such as a Teflon® film.

[0027] The heating device **117**, such as a ceramic heating strip, is positioned inside the fuser roller **115** and along its length. The heating strip can be silver based with a glass cover to reduce friction with the fuser roller ~~film~~ **115**. Other heating devices may include a quartz lamp, heating wires or other suitable heating elements as known in the art. The pressure roller **120** is, for example, constructed with a metal core and a pliable outer layer. The pressure roller **120** may also include a thin Teflon® release layer (not shown). After fusing the toner **45** to the print media **75**, output rollers **125** push the print media **75** into an output tray **130** and printing is complete.

[0028] With further reference to Figure 1, a voltage circuit **135** applies a bias voltage to the fuser roller **115** to keep toner particles from attaching to the fuser roller **115** when the print media **75** is passing through it. The bias voltage is applied at substantially a constant value, for example, -600 volts. It will be understood by those skilled in the art that the applied voltage can be other values and will change depending on the type of toner **45** used for printing. For example, when using a negative sign toner, the applied bias voltage is a negative voltage so that the toner is repelled from the fuser. When using a positive sign toner, the applied bias voltage is a positive voltage.

[0029] Although the bias voltage is applied at a constant voltage value, the voltage of the fuser does not remain constant. The fuser voltage changes as the print media **75** contacts the

fuser. Most types of print media 75 are electrically non-conductive and once it contacts the fuser, it enters the current path and changes the electrical properties of the system. In general, the print media 75 increases the capacitance of the system which causes a change in the fuser voltage. In other words, the presence or absence of the print media **75** in the fuser causes the fuser to have different voltage states, for example, a non-fusing voltage state and a fusing voltage state. To monitor and measure the voltage across the fuser, a fuser sensor circuit **140** is connected to the voltage circuit **135**. By monitoring the bias voltage on the fuser roller **115**, the ~~imaging device~~electrophotographic printer **10** can determine whether the print media 75 is in the fuser or not. This will be described in greater detail below and with reference to Figure 2.

[0030] With continued reference to Figure 1, the controller **65** also controls a high voltage power supply (not shown) to supply voltages and currents to components used in the electrophotographic processes, such as to the charge roller **15**, the developing roller **40**, the transfer roller **95** and the fuser. Furthermore, controller **65** controls a drive motor (not shown) that provides power to a gear train (not shown) and controls various clutches and paper feed rollers necessary to move the print media 75 through the printing path within the electrophotographic printer **10**. It will be appreciated that different imaging devices may have components and control mechanisms different than those shown in the exemplary system of Figure 1. One of ordinary skill will appreciate that the present invention will apply to other devices in accordance with their particular configuration and obvious modifications thereto.

[0031] With reference to Figure 2, one embodiment of the voltage circuit **135** and the fuser sensor circuit **140** is shown in an exemplary configuration with the fuser roller **115** and pressure roller **120**. As stated previously, the voltage circuit 135 applies a generally constant bias voltage to the fuser. For example, the voltage circuit **135** includes a voltage power source **200** that applies a negative voltage to the fuser roller **115** through a charger **205**. The charger **205** is an electrically conductive device that is in contact with the fuser roller **115**. For example, the charger **205** is a charge brush having fibers of electrically conductive material that contact the fuser roller **115** and charge it according to the bias voltage. The voltage circuit **135** is also electrically connected to the pressure roller **120** and the voltage circuit **135** is grounded at **210**.

The voltage circuit **135** is connected to the shaft of the pressure roller **120** or contacts other areas of the pressure roller **120** using other electrical contact devices as known in the art.

[0032] As described above, the bias voltage is applied to the fuser to keep toner particles from attaching to it. The bias voltage depends on the sign of the toner **45** (e.g. the bias voltage is negative for a negative sign toner, and positive for a positive sign toner.) An exemplary bias voltage may be about -600 volts when printing with a negative sign toner. Of course, other voltages can be used.

[0033] With further reference to Figure 2, as the print media **75** enters the fuser or otherwise comes in contact with the nip between the fuser roller **115** and the pressure roller **120**, the print media **75** changes the electrical properties of the fuser. Thus, the print media **75** changes the bias voltage of the fuser. The fuser sensor circuit **140** is connected to the voltage circuit **135** at a measuring point **215** to monitor and measure the bias voltage across the fuser. In the illustrated embodiment, the measuring point **215** is located on the signal line between the charger **205** and the ground **210**. Of course, it will be appreciated that other circuit configurations can be used. For example, the voltage can be measured directly from the fuser roller **115** or the pressure roller **120**. Using the fuser sensor circuit **140**, the controller **65** can determine whether the print media **75** is in the fuser or not by detecting a change in the measured bias voltage and/or analyzing the measured bias voltage. This information is useful when a paper jam occurs since it assists the imaging device to locate the paper and to generate an appropriate error signal.

[0034] In one embodiment, the fuser sensor circuit **140** includes a comparator logic **220** that has a reference voltage set to the applied bias voltage. The comparator logic **120** compares the measured bias voltage to the reference voltage and a difference value is computed. When the difference value passes a predetermined threshold value, the comparator logic **220** generates and stores a status signal **225** by, for example, setting a bit value. The status signal **225** indicates to the controller **65** that print media **75** is in the fuser. Alternately, the fuser sensor circuit **140** can use edge detection logic that detects changes in the measured bias voltage and sets the status signal **225** accordingly. In this case, the comparator logic **120** keeps track of whether the edge is

a leading or trailing edge in the measured voltage such that the corresponding change in voltage properly indicates that ~~the~~ print media 75 is in the fuser.

[0036] With reference to Figure 3, a flow diagram of a print process is shown. Figure 4 shows a flow diagram of an interrupt process that is initiated when a malfunction or other error is detected during the print process. When a print request and print data are received by the ~~imaging device~~electrophotographic printer **10**, an image is generated and transferred to one or more sheets of print media 75 in a continuous manner (blocks **300** and **305**). In this description, the print media 75 will be one or more sheets of paper. The fuser is maintained at a generally constant voltage by applying a predetermined bias voltage (block **310**). However, as a sheet of paper enters the fuser, the bias voltage changes due to the current path being altered by the paper. Throughout the process, the bias voltage across the fuser is measured (block **315**). An exemplary graph showing changes in the measured bias voltage is shown in Figure 5. Based on the measured bias voltage, a fuser status signal is set (block **320**) that indicates whether paper is in the fuser or not. The status signal is set, for example, by comparing the applied bias voltage to the measured voltage and setting the signal when the difference between the voltages passes a threshold.

[0037] The image is fused to the paper as it passes through the fuser with a process of heat and pressure as described above (block **325**). When the sheet of paper exits the fuser, the measured bias voltage returns to the applied voltage value causing the fuser status signal to be re-set indicating that the paper is not in the fuser. Each sheet is then outputted from the ~~imaging device~~electrophotographic printer 10 (block **330**) and the printing continues for the number of sheets required.

[0038] The controller **65** can check the fuser status signal at any desired time, along with other sensors and timing logic in the ~~imaging device~~electrophotographic printer 10, to determine the location of the paper while it is moving. With this information, it can determine if the paper has reached the fuser, did not reach the fuser, exited the fuser~~, etc~~ and the like. Checking the status signal is performed, for example, with an interrupt request that spawns a software routine to check the fuser sensor circuit **140**.

[0039] Figure 4 shows an exemplary interrupt process in accordance with one embodiment of the present invention. If a malfunction or other printing error occurs during the print process, the process is interrupted (block **400**). At some point during the interrupt, checks are made to determine if a paper jam has occurred (block **405**). If a jam has occurred, the system turns off power so that any high voltages or currents do not injure a user who is examining the ~~device~~electrophotographic printer **10** and attempts to determine the location of the paper jam (block **410**). As known in the art, any number of sensors can be positioned throughout the ~~imaging device~~electrophotographic printer **10** to assist in detecting error conditions including sensing the presence of paper.

[0040] To determine if paper is present in the fuser, the measured fuser bias voltage is checked (block **415**). This includes checking the fuser status signal which indicates whether paper is in the fuser. As described above, the status signal is set based on the measured fuser bias voltage being within a threshold of the applied bias voltage. To further assist in this determination, a fuser exit sensor may be used in conjunction with the bias voltage check to determine if a wrap jam has occurred. A wrap jam is when part of the print media **75** sticks to ~~the~~a fuser film and wraps around the heater/film assembly. If the location of the jam is determined, an error message is displayed which indicates the location (block **420**). The message may be in the form of a visual signal, an audible signal, a text message or a combination of these. The system then waits for the jam to be corrected (block **425**) before printing is resumed (block **430**).

[0041] With further reference to Figure 4, if the interrupt occurred due to an error condition other than a paper jam, other diagnostics are performed (block **435**) to determine the error as known in the art. When the error condition is determined, an associated error message is displayed (block **440**). If the error is critical (block **445**) such that printing cannot resume, the system waits for corrective action, typically requiring human intervention, to cure the problem (block **450**) before printing is resumed. Exemplary critical errors may include incorrect paper size, out of paper, out of toner, a communication error, and the like. A non-critical error which allows printing to continue may include a low toner condition.

[0042] In an alternative embodiment, Figures 3 and 4 represent a flow diagram showing the processing performed by the ~~imaging system~~electrophotographic printer **10** as executable instructions that control the components of ~~the~~an imaging system. The rectangular elements denote "processing blocks" and represent computer software instructions or groups of instructions. The diamond shaped elements denote "decision blocks" and represent computer software instructions or groups of instructions which affect the execution of the computer software instructions represented by the processing blocks. Alternatively, the processing and decision blocks represent steps performed by functionally equivalent circuits such as a digital signal processor circuit or an application specific integrated circuit (ASIC). The flow diagram does not depict syntax of any particular programming language. Rather, the flow diagram illustrates the functional information one skilled in the art requires to fabricate circuits or to generate computer software to perform the processing of the system. It should be noted that many routine program elements, such as initialization of loops and variables and the use of temporary variables are not shown. It will also be appreciated by one of ordinary skill in the art that elements embodied as software may be implemented using various programming approaches such as machine language, procedural, object oriented or artificial intelligence techniques. It will further be appreciated that, if desired and appropriate, some or all of the software can be embodied as part of a device's operating system.

[0043] Illustrated in Figure 5 is a graph **500** showing an exemplary measured bias voltage across the fuser as measured during a print cycle over time. As the printing begins, the fuser is charged **505** to a negative bias voltage of about -600 volts. As a sheet of paper enters the fuser, the paper changes the fuser bias voltage such that the measured bias voltage becomes about -530 volts. This is shown at point **510**. When the sheet leaves the fuser, the measure voltage returns to the applied voltage of -600 volts (shown at point **515**) since the paper is no longer interfering with the current path of the fuser. This cycle is repeated for each sheet of paper. Of course, it will be appreciated that the voltages used can be different from the values described. As long as print media **75** enters the fuser nip and changes the voltage, the changed voltage can be measured and the presence of paper can be determined.

[0044] Illustrated in Figure 6 is another embodiment of the fuser sensor circuit **140** to detect a change in the bias voltage on the fuser. In one form, the circuit is connected to the fuser (for example via a carbon brush or other electrically conductive connection) and a switch **Q1** turns on or off based on the bias voltage detected. The output from the switch **Q1**, which is considered a status signal, is read by the controller **65** or other sensor logic when desired to check its status. The switch **Q1** may be a PNP transistor, an NPN transistor, a MOSFET or other type of switch. It will be appreciated that the configuration of the switch **Q1** will change based on the type of bias voltage applied to the fuser and/or its polarity. This may include changing the exemplary 3.3V voltage at its collector. Thus, depending on the type of transistor, its output may be received from either the collector or emitter depending on the configuration.

[0045] Controlling the transistor's response may be a resister **R1** having a resistance value that causes the ~~transistor~~switch **Q1** to turn on or shut off based on the bias voltage. A diode **D1** can be inserted between the circuit and the fuser to control the passage of current. The orientation of the diode **D1** depends on the polarity of the bias voltage. A capacitor **C1** can be included to provide a smoothing function. Optionally, a resistor **R2** can be used if desired. With this circuit, as paper enters the nip of the fuser, the voltage across resister **R1** changes which triggers the ~~transistor~~switch **Q1** to change its state (on or off), thus changing its output status signal. This indicates that paper has entered the fuser. Of course, the circuit can be configured to cause the ~~transistor~~switch **Q1** to change its status after a selected amount of voltage change has occurred such as a change that passes a threshold.

[0046] In an alternative embodiment, the fuser sensor circuit **140** is configured as a separate circuit which is not connected to the voltage circuit **135**. Instead, the fuser bias voltage is measured from ~~the~~a film of the fuser roller **115** by, for example, a conductive brush in electrical contact with the film.